HEALTH ADVISORY AND SAFE EATING GUIDELINES FOR FISH FROM FOLSOM LAKE AND LAKE NATOMA (SACRAMENTO, EL DORADO AND PLACER COUNTIES)

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FOREWORD

This report provides guidelines for consumption of various fish species taken from Folsom Lake in Sacramento, El Dorado and Placer counties as well as revision of a previous state advisory for Lake Natoma in Sacramento County. These guidelines were developed as a result of studies of mercury concentrations in fish tested from these water bodies, and are provided to fish consumers to assist them in making choices about the types of fish and frequency of consumption considered safe to eat. Some fish tested from these water bodies showed high mercury levels and guidelines are provided to protect against possible adverse health effects from methylmercury as consumed from mercury-contaminated fish. Additionally, the guidelines provide information to aid consumers in selecting fish that are lower in mercury or other contaminants. This report provides background information and a description of the data and criteria used to develop the guidelines.

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EXECUTIVE SUMMARY

Mercury levels were evaluated in edible tissues of fish caught from Folsom Lake in Sacramento, El Dorado and Placer counties, an area possibly affected by historic gold mining. Mercury levels in fish were collected and analyzed by the U.S. Geological Survey for the U.S. Bureau of Reclamation. The contaminant data were evaluated by the Office of Environmental Health Hazard Assessment (OEHHA) to determine whether there may be potential adverse health effects associated with the consumption of certain sport fish from this water body and to identify fish species with low contaminant levels considered safe to eat frequently. Based on this evaluation, a health advisory and safe eating guidelines were developed that allow fishers to select fish to eat from Folsom Lake in quantities that maintain mercury exposures within safe levels while supporting the health benefits of fish consumption. Additionally, a previous state advisory for Lake Natoma in Sacramento County was revised using the newly developed advisory tissue levels (ATLs) for mercury and other contaminants. Lake Natoma is a 500-acre afterbay for Folsom Lake Dam. With the exception of catfish, mercury contaminant data for the two connected water bodies were similar; therefore, unified fish consumption guidelines for Folsom Lake and Lake Natoma were deemed justified.

Mercury contamination of fish is a national problem that has resulted in the issuance of fish consumption advisories in most states, including California. Mercury is a trace metal that can be toxic to humans and other organisms in sufficiently high doses. Mercury occurs naturally in the environment and is also redistributed as a result of human activities such as mining and the burning of fossil fuels. Once mercury is released into the environment, it cycles through land, air, and water. In aquatic systems, it undergoes chemical transformation to the more toxic organic form, methylmercury, which accumulates in fish and other organisms. Almost all fish contain detectible levels of mercury, more than 95 percent of which occurs as methylmercury. Consumption of fish is the major route of exposure to methylmercury in the United States. For more information on mercury in fish, see Appendix 1.

The critical target of methylmercury toxicity is the nervous system, particularly in developing organisms such as the fetus and children. Methylmercury toxicity can occur to the fetus during pregnancy even in the absence of symptoms in the mother. In 1985, the United States Environmental Protection Agency (U.S. EPA) set a reference dose (that is the daily exposure likely to be without significant risks of deleterious effects during a lifetime) for methylmercury of $3x10^{-4}$ milligrams per kilogram of body weight per day (mg/kg-day), based on central nervous system effects (ataxia, or loss of muscular coordination; and paresthesia, a sensation of numbness and tingling) in adults. This reference dose (RfD) was lowered to $1x10^{-4}$ mg/kg-day in 1995 (and confirmed in 2001), based on neurodevelopmental abnormalities in infants exposed *in utero*.

OEHHA finds convincing evidence that the fetus is more sensitive than adults to the neurotoxic effects of mercury, but also recognizes that fish play an important role in a healthy diet, particularly when it replaces other, higher fat sources of protein. These potential beneficial effects are thought to stem largely from unique fatty acids found in fish (docosahexaenoic and eicosapentaenoic acids) and include reduced rates of cardiovascular disease and stroke, decreased inflammation, and improvements in cognitive and visual function. Fish consumption during pregnancy, in particular, has been associated with higher cognitive scores in young children. Nevertheless, because the fetus has increased vulnerability to methylmercury, OEHHA will use the current U.S. EPA RfD, based on effects in the fetus, for women of childbearing age (18-45 years) and children 1-17 years. At the same time, OEHHA will encourage women 18-45 to select and eat fish that are low in mercury or other contaminants and high in the fatty acids described above, which can benefit the developing fetus. The previous U.S. EPA RfD, based on effects in adults, will be used for women over 45 years and men, who are generally less sensitive to methylmercury.

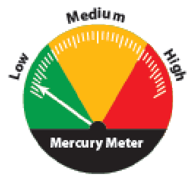
In order to provide fish consumption guidelines for various fish species, contaminant concentrations in fish from a water body are compared to OEHHA ATLs for those chemicals, which are designed to determine the appropriate consumption rate (quantity of fish or shellfish consumed in a given time period) that would prevent exposure to more than the average daily RfD for non-carcinogens or a cancer risk level greater than $1x10^{-4}$ (one in 10,000) for carcinogens. Best professional judgment is used to determine the most suitable data evaluation approach as well as the most appropriate method to convert a complex data set into more simplified and unified consumption advice for risk communication purposes. Ultimately, a health advisory and safe eating guidelines identify those fish species with high contaminant levels whose consumption should be avoided as well as those low-contaminant fish that may be consumed frequently as part of a healthy diet. A statistically representative sample size was available to provide consumption advice for bluegill, redear sunfish, channel catfish, Chinook salmon, rainbow trout, largemouth bass, and spotted bass. Supporting data (such as mercury concentration for a closely related species at a similar trophic level) were used to develop additional consumption guidelines for green sunfish (and other sunfish), other trout species, white catfish, and smallmouth bass from these two water bodies.

For general advice on how to limit your exposure to chemical contaminants in sport fish (e.g., eating smaller fish of legal size), as well as a fact sheet on methylmercury in sport fish, see the California Sport Fish Consumption Advisories (http://www.oehha.ca.gov/fish.html) and Appendices 1 and 2. Guidelines for other California water bodies can be found online at: http://www.oehha.ca.gov/fish/so_cal/index.html. It should be noted that, unlike the case for many chlorinated hydrocarbon contaminants, such as DDTs and PCBs, various cooking and cleaning techniques will not reduce the methylmercury content of fish. Additionally, there are no known ways to prepare fish (such as soaking in milk) that will reduce the methylmercury content of the fish.

Guide to Eating Fish Caught in
Folsom Lake
and
Lake Natoma

A guide to eating fish caught in Folsom Lake and Lake Natoma

Women 18 - 45, especially those who are pregnant or breastfeeding, and children 1 - 17



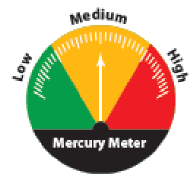
Trout ♥
16 inches long or less

Bluegill

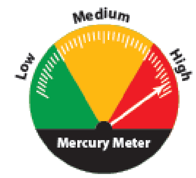
Green Sunfish and
Other Sunfish

♥ = High in Omega-3s

Safe to eat 2 servings per week



There are no fish with medium levels of mercury



Largemouth, Smallmouth, and
Spotted Bass

Chinook (King) Salmon

Catfish

Trout
over 16 inches long

Do not eat

Men over 17 and women over 45 can safely eat more fish

- **Safe to eat 5 servings per week**
- There are no fish with medium levels of mercury
- **Safe to eat 1 serving per week** except catfish from Lake Natoma — DO NOT EAT

♥ Why eat fish?

Eating fish is good for your health. Fish have Omega-3s that can reduce your risk for heart disease and improve how the brain develops in unborn babies and children.

What is the concern?

Some fish have high levels of mercury that can negatively affect how the brain develops in unborn babies and children.

What is a serving?

For Adults **For Children**

The recommended serving of fish is about the size and thickness of your hand. Give children smaller servings.

Fish buying guidelines for women 18 – 45 and children 1 – 17

Do not eat fish caught by family and friends in the same week that you eat fish bought in a store or restaurant. For fish that you buy:

- **Safe to eat 2 servings per week** of low mercury fish such as salmon ♥, pollock, catfish, tilapia, shrimp, anchovies ♥, sardines ♥, trout ♥, and canned chunk-light tuna

OR

- **Safe to eat 1 serving per week** of medium-mercury fish such as canned albacore (white) tuna ♥
- **Do not eat** shark, swordfish, tilefish, or king mackerel

California Office of Environmental Health Hazard Assessment
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INTRODUCTION

Mercury is a trace metal that occurs naturally in the environment, and exists in various forms including elemental or metallic mercury, inorganic, and organic mercury (ATSDR, 1999; IARC, 1993). Mercury enters the environment from the breakdown of minerals in rocks and leaching from old mine sites. Cinnabar ores, naturally rich in mercury, are common in northern California, and mercury was extensively mined in California in the 1800s and early 1900s. Mercury is also emitted into air from cement kilns, the burning of fossil fuels, and other industrial sources, as well as from volcanic eruptions. Mercury contamination thus occurs as a result of both natural and anthropogenic sources and processes.

Once mercury is released into the environment, it cycles through land, air, and water. The deposition of mercury in aquatic ecosystems is a concern for public and environmental health because microorganisms (bacteria and fungi) in the sediments can convert inorganic mercury into organic methylmercury, a more toxic form of mercury. Once formed, methylmercury is ingested by aquatic animals and subsequently by the fish that feed on them. In this way, methylmercury "biomagnifies," reaching the highest levels in fish and other organisms at the top of the food web. Concentrations of methylmercury in fish tissues can therefore be orders of magnitude greater than concentrations found in the water in which they reside.

Methylmercury contamination of fish is a national problem that has resulted in the issuance of fish consumption advisories in most states, including California (U.S. EPA, 2003). Methylmercury can be toxic to humans and other organisms in sufficiently high doses and can pose a variety of human health risks (NRC/NAS, 2000). Fish consumption is the major route of exposure to methylmercury in the United States (ATSDR, 1999). Almost all fish contain detectable levels of this chemical, more than 95 percent of which occurs as methylmercury. For this reason, concentrations in fish are usually measured as total mercury, and the conservative assumption is made that measured mercury is methylmercury. "Mercury" and "methylmercury" may thus be used interchangeably in this report. Whether consumption of fish is harmful depends on the concentrations of methylmercury in the fish and the amount of fish consumed.

Human toxicity of methylmercury has been well studied following several epidemics of human poisoning resulting from consumption of highly contaminated fish (Japan) or seed grain (Iraq, Guatemala, and Pakistan; Elhassani, 1982-83). The resulting illness was manifested largely by neurological signs and symptoms such as loss of sensation in the hands and feet and, in extreme cases, loss of gait coordination, slurred speech, sensory deficits including blindness, and mental disturbances (Bakir et al., 1973; Marsh, 1987). Review of data collected during and subsequent to the Japan and Iraq outbreaks identified the critical target of methylmercury as the nervous system and the most sensitive subpopulation as the developing organism (U.S. EPA, 1997). During critical periods of prenatal and postnatal structural and functional development, the fetus and children are especially susceptible to the toxic effects of methylmercury (ATSDR, 1999; IRIS, 1995). For additional discussion of the toxicity of methylmercury, see Klasing and Brodberg (2008).

Risks from exposure to methylmercury in fish are evaluated by comparing measured concentrations to a reference dose (RfD), which is an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime (including to sensitive population subgroups), and is expressed in units of milligrams per kilogram per day (mg/kg-day; IRIS, 1995). This estimate includes a safety factor to account for data uncertainty. The underlying assumption of an RfD is that, unlike carcinogenic effects, there is a threshold dose below which certain toxic effects will not occur. The RfD for a particular chemical is derived from review of relevant toxicological and epidemiological studies in animals or humans. Based on these values and the application of uncertainty factors to account for incomplete data and sensitive subgroups of the population, an RfD is then generated. Exposure to a level above the RfD does not mean that adverse effects will occur, only that the possibility of adverse effects occurring has increased (IRIS, 1993).

The first U.S. Environmental Protection Agency (U.S. EPA) RfD for methylmercury was developed in 1985 and set at $3x10^{-4}$ mg/kg-day (U.S. EPA, 1997). This RfD was based on the earliest symptom of methylmercury toxicity (paresthesias or numbness and tingling sensations) that occurred in a small percentage of exposed Iraqi adults. U.S. EPA applied a 10-fold uncertainty factor to the lowest adverse effect level to generate the RfD (U.S. EPA, 1997). In 1995, U.S. EPA had sufficient data from Marsh *et al.* (1987) and Seafood Safety (1991) to develop an oral RfD based on methylmercury exposures during the prenatal stage of development (IRIS, 1995). The oral RfD from these studies was set at $1x10^{-4}$ mg/kg-day, including a 10-fold uncertainty factor, to protect against developmental neurological abnormalities in infants (IRIS, 1995). This fetal RfD was deemed protective of infants and sensitive adults.

Recently, the National Academy of Sciences (NAS) was directed to provide scientific guidance to U.S. EPA on the development of a new RfD for methylmercury (NRC/NAS, 2000). Three large prospective epidemiological studies were evaluated in an attempt to provide more precise dose-response estimates for methylmercury at chronic low-dose exposures, such as might be expected to occur in the United States. The three studies were conducted in the islands (the Faroe Island, the Seychelle Islands, and New Zealand) where the residents' diets rely heavily on consumption of fish and marine mammals, which provide a continual source of methylmercury exposure (NRC/NAS, 2000). The NAS report supported the current U.S. EPA RfD of $1x10^{-4}$ mg/kg-day for fetuses, but suggested that it should be based on the Faroe Islands study rather than Iraqi data. U.S. EPA has since published an updated RfD document that arrives at the same numerical RfD as the previous fetal RfD, using data from all three recent epidemiological studies while placing emphasis on the Faroe Island data (IRIS, 2001). For additional discussion of the derivation of the RfD for methylmercury, see Klasing and Brodberg (2008).

The Office of Environmental Health Hazard Assessment (OEHHA) is the agency responsible for evaluating public health impacts from chemical contamination of sport fish, and issuing advisories, when needed, for the state of California. OEHHA's authorities to conduct these activities are based on mandates in the California Health and Safety Code, Section 59009, to protect public health, and Section 59011, to advise local health authorities; and the California Water Code Section 13177.5, to issue health advisories. Fish advisories developed by OEHHA are published in the California Sport Fishing Regulations of the California Department of Fish and Game (CDFG). OEHHA now emphasizes "safe eating guidelines" in these advisories in an effort to inform consumers of healthy choices in fish consumption as well as those that should be avoided or restricted. For advisories based on mercury levels in fish, OEHHA will use two separate RfDs to assess risk for different population groups. The current RfD of $1x10^{-4}$ mg/kg-day, based on effects in infants, will be used for women 18-45 years, including pregnant and breastfeeding women, and children 1-17 years. The previous RfD of 3×10^{-4} mg/kg-day, based on effects in adults, will be used for women over 45 years and men.

Although evaluating contaminants that may be found in fish must be of primary concern, OEHHA has also determined that there is a significant body of evidence and general scientific consensus that eating fish at dietary levels that are easily achievable, but well above national average consumption rates, appears to promote significant health benefits, including decreased mortality. These potential beneficial effects are thought to stem largely from unique omega-3 fatty acids found in fish (docosahexaenoic acid or DHA and eicosapentaenoic acid or EPA) and include reduced rates of cardiovascular disease and stroke, decreased inflammation, and improvements in cognitive and visual function. Fish consumption during pregnancy, in particular, has been associated with higher cognitive scores in young children. In order to take these benefits into account and best promote the overall health of the fish consumer, OEHHA has expanded the advisory process beyond a simple risk paradigm (see Klasing and Brodberg [2008] for more discussion). OEHHA encourages people of all ages, especially women 18-45 years and children, to select and eat fish that are low in mercury or other contaminants and high in omega-3 fatty acids (DHA and EPA).

BACKGROUND

Elevated levels of mercury associated with historic gold and mercury mining have been found in fish in numerous reservoirs and stream sites in northern California. As a result, fish consumption advisories based on mercury contamination have been issued by OEHHA for various water bodies in at least 29 counties in central and northern California. In an effort to assess mercury levels in fish from other northern California water bodies that may have been impacted by mining or other sources of mercury, samples were collected from Folsom Lake (see Figure 1) by the U.S. Geological Survey (USGS) for the U.S. Bureau of Reclamation (USBR). Additionally, data collected in 2002 and 2003 from Lake Natoma and used to issue a previous state advisory (Klasing and Brodberg, 2004) were reevaluated based on the newly revised advisory tissue levels (ATLs; see Klasing and Brodberg, 2008).

Folsom Lake and Lake Natoma

Located approximately 25 miles east of Sacramento, Folsom Lake was formed by the 1956 completion of Folsom Dam on the north and south forks of the American River. When full, Folsom Lake holds over 1,000,000 acre feet of water with 75 miles of shoreline. With between two and three million visitors annually, Folsom Lake is the most popular year-round multi-use facility in the state park system (Crocket, 2007; USBR, 2007a, 2007b).

Significant gold mining activity occurred in the Folsom Lake area from 1849 until 1962. The Folsom mining district dredge field, located near the town of Folsom, covered approximately 70 square miles and was one of the largest dredging fields in the state (Clark, 1998). Mercury was often used in this process to aid in the recovery of gold (Hunerlach and Alpers, 2003) and, as a result, may have contaminated nearby water bodies.

Folsom Lake is known for excellent bass and trout fishing, from either bank or boat. The lake also boasts a significant catfish, crappie, and Chinook salmon fishery (Stienstra, 2004). In 2006, (CDFG) planted approximately 30,000 catchable-sized rainbow trout in Folsom Lake, as well as approximately 27,000, 60,000, and 118,000 fingerling rainbow trout, Kokanee, and Chinook salmon, respectively (Dave Krueger, written communication).

Lake Natoma is a 500-acre afterbay for Folsom Lake Dam on the American River, just east of Sacramento, California (Stienstra, 1999). Local water conditions result in some of the largest rainbow trout in California (Stienstra, 1999), including a 23-pound state inland record resident rainbow trout (CDFG, 2008). Other sport fish caught in the lake include various bass and catfish species, green and redear sunfish, black crappie, and bluegill.

Data Collection and Evaluation

As noted above, Folsom Lake data used in this report originated from the USBR (May and Brumbaugh, 2005; 2006). Mercury concentrations were determined on 46 fish collected in 2004 (6 largemouth bass, 1 smallmouth bass, 15 spotted bass, 10 channel catfish, 1 white catfish, 6 rainbow trout, 4 Chinook salmon, 1 green sunfish, and 2 bluegill) and 23 fish collected in 2006 (1 spotted bass, 13 rainbow trout, and 9 bluegill). Mercury concentrations were also analyzed for an additional 7 Chinook salmon and one rainbow trout collected in 2007. Fish were collected using electrofishing equipment; all fish met legal or edible size criteria (see size criteria in footnotes of Table 1). Fish were measured in fork length and filleted; skinless fillets were homogenized and lyophilized, with mercury concentrations determined on duplicate fillet samples using a direct mercury analyzer at USGS Columbia Environmental Research Center (CERC). The mean of the two analyses was reported on a wet weight basis using moisture contents determined during lyophilization.

It is not possible to determine in advance how many samples of each fish species from each site will be necessary in order to statistically interpret contamination data for fish consumption guidelines. However, U.S. EPA does recommend a minimum of three replicate composite samples of three fish per composite (nine total fish) in order to begin assessing the magnitude of contamination at a site. U.S. EPA also recommends that at least two fish species be sampled per site. Although composite analysis is generally the most cost-efficient method of estimating the average concentration of chemicals in a fish species, individual sampling provides a better measure of the range and variability of contaminant levels in a fish population (U.S. EPA, 2000a). Using these guidelines, OEHHA believes that a minimum of three replicates of three fish per composite or, preferably, nine individual fish samples of multiple species from each site should be analyzed for this type of pilot study. Fish samples should be collected from multiple (legal/edible-) size classes. Following this sampling protocol will allow estimation of the range and variation of contaminant concentrations at a particular site and derivation of a representative mean concentration for use in developing fish consumption guidelines. More samples will provide a better estimate of the mean contaminant level in various fish species and are especially important for large water bodies.

Of the samples collected from Folsom Lake, bluegill (n = 11), channel catfish (n = 10), Chinook salmon (n = 11), spotted bass (n = 16), and rainbow trout (n = 20), had sufficient sample size

(≥ 9 fish per species) of legal/edible size fish (see Table 1) to be considered representative of mercury levels in those species, thereby allowing adequate estimation of the health risks associated with their consumption. Interpretation of data for other fish when there is a limited sample size can be found in the guidelines for fish consumption section of this report.

Researchers from USGS and the University of California – Davis (UCD) collected a total of 11 fish species by electrofishing equipment or gill nets in August 2000, from September to October 2002, and in July 2003, at several sites in Lake Natoma, including the vicinity of Negro Bar and Mississippi Bar, the mouths of Willow Creek and Alder Creek, Natomas Slough, and near Nimbus Dam (Saiki et al., 2004; Alpers et al., 2004). Species collected included largemouth bass, smallmouth bass, spotted bass, channel catfish, white catfish, brown bullhead, black bullhead, redear sunfish, green sunfish, bluegill, and rainbow trout. Fish were measured and weighed; boneless and skinless individual fillets were submitted to UCD (the August, 2000 and July, 2003 samples) or the USGS CERC in Columbia, Missouri, (the September to October, 2002 samples) for total mercury analyses by atomic absorption spectrophotometry using either a Perkin Elmer Flow Injection Mercury System or a Milestone DMA-80 analyzer.

Of the samples collected at Lake Natoma, largemouth bass (n = 23), bluegill (n = 78), channel catfish (n =11), and redear sunfish (n = 11) had sufficient sample size of legal/edible size fish (see Table 2) to be considered representative of mercury levels in those species, thereby allowing adequate estimation of the health risks associated with their consumption.

MERCURY LEVELS IN FISH FROM FOLSOM LAKE AND LAKE NATOMA

Mercury concentrations in fish and other biota are dependent on the mercury level of the environment, which can vary based on differences in pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology of individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989). Other factors also affect the accumulation of mercury in fish tissue, including fish diet, species and age (as inferred from length) (WHO, 1989; 1990). Fish at the highest trophic levels (i.e., predatory fish) generally have the highest levels of mercury. Additionally, because of the long biological half-life of methylmercury in fish (approximately 2 years), tissue concentrations in fish increase with increased duration of exposure (Krehl, 1972; Stopford and Goldwater, 1975; Tollefson and Cordle, 1986). As a result, tissue methylmercury concentrations are expected to increase with increasing age and length within a given species, particularly in piscivorous fish.

Chemical concentrations for the data presented below are reported in wet weight. Arithmetic means, rather than geometric means, were used to represent the central tendency (average) of mercury concentrations for all species in this report. In general, arithmetic means for environmental chemical exposures are more health-protective than geometric means, and are commonly used in human health risk assessments. For legal/edible sized fish, the mean mercury concentration, length, and sample size for each species collected and analyzed from Folsom Lake are presented in Table 1. Complete descriptive statistics for these fish can be found in Appendix

3. All fish lengths that were reported in fork length were converted to total length for the purpose of calculating mean lengths; conversion factors for estimating total length from measured fork lengths were developed for each species by OEHHA based on the degree of the angle in the fork of the tail fin. The lengths as originally reported, however, are included in Appendix 4, which also contain the individual mercury concentrations and lengths of legal/edible size fish from which species means were generated.

Mercury concentrations in legal/edible size fish of all species from the Folsom Lake ranged from 0.031 ppm in a rainbow trout to 1.2 ppm in a spotted bass. For those species collected with sufficient sample size to adequately represent mercury levels (n ≥ 9 fish), the following mercury concentrations and fish lengths were reported for edible/legal-sized fish: mean mercury concentration for bluegill was 0.12 ppm, with a range of 0.07 to 0.18 ppm; lengths ranged from 131 to 189 mm in this species, with a mean of 152 mm. Mercury levels in channel catfish averaged 0.51 ppm, with a range of 0.37 to 0.65 ppm. Channel catfish ranged in length from 529 to 736 mm, with a mean of 624 mm. Chinook salmon from Folsom Lake had a mean mercury concentration of 0.54 ppm (range: 0.042 to 1.0 ppm) and a mean length of 390 mm (range: 289 to 567 mm). Mercury concentrations in rainbow trout ranged from 0.03 to 0.91 ppm, with a mean of 0.18 ppm; lengths in this species ranged from 247-472 mm, with a mean of 330 mm. Spotted bass had a mean mercury concentration of 0.71 ppm (range: 0.36 to 1.2 ppm) and a mean length of 393 mm (range: 326 to 499 mm).

The mean mercury concentration, length, and sample size for each species collected and analyzed from Lake Natoma are presented in Table 2. Complete descriptive statistics for each fish species sampled from Lake Natoma can be found in Appendix 5; individual mercury concentrations and fish lengths from which species means were generated can be found in Appendix 6. Individual mercury concentrations and fish length for fish below legal or edible lengths are presented in Appendix 7. Only legal and/or edible size fish were included in all analyses. Mercury concentrations in legal/edible size fish of all species ranged from 0.02 ppm in a rainbow trout to 1.89 ppm in a large (750 mm) channel catfish. For those species with sufficient sample size to adequately represent mercury levels for fish in that water body (n ≥ 9 fish), the mean mercury concentration for largemouth bass was 0.57 ppm, with a range of 0.27 to 0.92 ppm. Largemouth bass ranged in length from 315 to 490 mm, with a mean of 387 mm. Mercury concentrations in channel catfish ranged from 0.96 ppm to 1.89 ppm, with a mean of 1.47 ppm. Lengths in this species ranged from 505 mm to 750 mm and averaged 635 mm. The mean mercury concentration in bluegill was 0.09 ppm, while the mean length for this species was 126 mm. Redear sunfish contained a mean mercury level of 0.10 ppm and had a mean length of 145 mm. Black bullhead, brown bullhead, green sunfish, rainbow trout, spotted bass, and white catfish were not collected in sufficient numbers to provide a representative sample. Assessment of those species, and other fish that may exist in either lake, are addressed in the guidelines for fish consumption section of this report.

GUIDELINES FOR FISH CONSUMPTION FOR FOLSOM LAKE AND LAKE NATOMA

OEHHA has developed advisory tissue levels (ATLs) for methylmercury and other contaminants found in fish (Klasing and Brodberg, 2008) similar to risk-based consumption limits recommended by U.S. EPA (2000b). ATLs relate the number and size of recommended fish meals to methylmercury concentrations found in fish (Table 3). These values were designed so that individuals consuming no more than a preset number of meals should not exceed the RfD for methylmercury or other non-carcinogenic contaminants, on average, or a risk level of $1x10^{-4}$ for carcinogens. ATLs for methylmercury for women over 45 years and men are approximately three times higher than for sensitive populations because of the three-fold higher RfD used for this population group. The sensitive population is defined as women of childbearing age (18-45 years), including women who are pregnant or breastfeeding, and children aged 1-17 years. Meal sizes were based on a standard eight-ounce (227 grams) portion of uncooked fish, which is approximately six ounces after cooking, for adults who weigh roughly 70 kilograms (equivalent to 154 pounds). OEHHA recommends that people who weigh less than 70 kilograms eat smaller portions of fish and that, in particular, children up to age 12 eat about half as much. A description of the process of developing ATLs, including other assumptions, can be found in Klasing and Brodberg (2008).

OEHHA generally issues site-specific consumption advice beginning at a consumption frequency of one eight-ounce serving per week (a total of six ounces of cooked fish per week), which is equivalent to two three-ounces servings or the minimum weekly fish consumption rate recommended by the American Heart Association (AHA, 2008). Fish that can be eaten at this frequency represent fish with relatively low levels of mercury and/or other contaminants. If, based on very low contaminant concentrations, fish can be consumed even more frequently than a total of six ounces per week, advice for consumption of two or three meals per week, or more, as appropriate, may also be provided. ATLs for four, five, six, and seven servings per week can be calculated, as in Klasing and Brodberg (2008), using consumption rates of 128, 160, 192, and 224 g/d, respectively. In addition, because of the potential beneficial effects from regular fish consumption, thought to stem largely from unique omega-3 fatty acids in fish, OEHHA encourages people of all ages, especially women 18-45 years and children 1-17, to eat fish that are low in mercury or other contaminants and high in omega-3 fatty acids. OEHHA recommends that consumers avoid regular consumption of fish that cannot be safely eaten at a minimum of six ounces (after cooking) a week.

Folsom Lake and Lake Natoma are connected water bodies and, as such, are likely to have similar contaminant levels in the same or similar fish species. Review of fish contaminant data for the two lakes showed this to be largely the case, with only channel catfish having remarkably different mercury levels between Folsom Lake and Lake Natoma. Thus, for the purposes of issuing a health advisory and safe eating guidelines, and with the exception of catfish, data from the two lakes were combined. Separate consumption advice was issued for combined species of catfish for the two water bodies.

Mean mercury concentrations for all fish species with a minimum of nine fish per sample were compared to the ATLs, as discussed above, to develop consumption guidelines. As noted above, for Folsom Lake and Lake Natoma, sample size was sufficient to issue fish consumption guidelines for bluegill, channel catfish, Chinook salmon, rainbow trout, redear sunfish, largemouth bass, and spotted bass. Although the overall mean mercury concentration for rainbow trout at Folsom Lake was relatively low (0.18 ppm), the range (0.03 to 0.91 ppm) was approximately 30-fold; the range for rainbow trout length (247 mm to 471 mm) was also substantial. To test whether data supported issuing separate advice for different lengths of rainbow trout, a regression analysis was performed to compare mercury concentration and length in this species (Figure 2). A quadratic curvilinear fit was the best fit to represent the length/mercury relationship. With mercury as the dependent variable, and length represented by a subset variable (length and length-square), 81 percent of mercury variance was accounted for by length. Thus, it seemed reasonable to provide consumption advice for rainbow trout based on fish length. Based on this analysis, mercury concentration exceeded the threshold between consumption and no consumption for women 18-45 years and children 1-17 years when rainbow trout were about 415 mm, or approximately 16 inches, in length (see Figure 2). Similarly, rainbow trout over 415 mm fell into the one serving per week category for women over 45 years and men. Thus, women of 18-45 years and children 1-17 are advised not to consume rainbow trout greater than 16 inches in length while women 45 years and older and men will be advised to consume rainbow trout no more than once per week.

When sample size for a particular species from a water body is too small to assure a statistically representative sample, other information may be useful to help develop consumption recommendations for that species. When there are less than nine individual or three composite samples at a site for a given species, advice for that species may be extrapolated from data for other, similar species at that site or from the same species at a similar site. This method is acceptable when evaluation of the entire data set shows clear trends that justify the issuance of prudent, protective health advice even in the absence of a statistically representative sample. For example, it may be reasonable to provide consumption advice for a particular species with few or no data (e.g., smallmouth bass) when adequate data are available for another, related fish species at that site (e.g., spotted bass).

For Folsom Lake and Lake Natoma, supporting data were examined to determine whether they could be used to assist in the development of fish consumption advice. Because different species of black bass often contain similar levels of the same contaminant in the same water body, it is recommended that consumers follow the advice for spotted bass and largemouth bass for smallmouth bass that may be caught in these water bodies. Similarly, different species of trout often contain comparable levels of contaminants. Thus, it is recommended that consumers follow the rainbow trout advice for other trout species that may be caught in these water bodies. Green sunfish and white catfish were also not collected in sufficient numbers from Folsom Lake to provide a statistically valid sample. OEHHA recommends that fishers follow the bluegill and redear sunfish advice for green sunfish and follow the channel catfish advice for white catfish caught in these water bodies.

Recommendations for women 18-45 years, including pregnant and breastfeeding women, and children 1-17 years for eating fish from Folsom Lake and Lake Natoma

- Women 18-45 years and children 1-17 years can eat a total of two servings a week from the following species: rainbow or other trout species less than 16 inches in length, bluegill, redear sunfish, or green sunfish. Serving size for women is six ounces of fish after cooking (equal to eight ounces before cooking). Serving size can be adjusted to add one ounce for every 20 pounds above, or subtract one ounce for every 20 pounds below, the average weight of 160 pounds. Serving size for children up to age 12 is about half as much as adults (3 ounces of cooked fish).

- Women 18-45 years and children 1-17 years should not eat any largemouth bass, smallmouth bass, spotted bass, Chinook (King) salmon, or catfish from Folsom Lake or Lake Natoma. Additionally, they should not eat rainbow or other trout species over 16 inches in length.

Recommendations for women over 45 years and men for eating fish from Folsom Lake and Lake Natoma

- Women over 45 years and men can eat five servings a week of rainbow or other trout species less than 16 inches in length, bluegill, redear sunfish, or green sunfish. Serving size is six ounces of fish after cooking (about eight ounces before cooking) for an adult weighing about 160 pounds. Serving size can be adjusted to add one ounce for every 20 pounds above, or subtract one ounce for every 20 pounds below, the average weight of 160 pounds.

- As an alternative, women over 45 years and men can eat one serving a week from the following species: rainbow trout or other trout species over 16 inches in length, largemouth bass, smallmouth bass, spotted bass, catfish (from Folsom Lake only), or Chinook salmon.

- Women over 45 years and men should not eat catfish from Lake Natoma.

Other Recommendations

Regular consumption of fish is recommended as part of a healthy diet due to evidence for health benefits associated with consistent fish consumption (AHA, 2008, IOM, 2007). The “one meal a month” advice used in the previous Lake Natoma advisory has been combined with the “no consumption” category in recent advisory tables and labeled “do not eat” to reflect that eating fish from this category is not health protective because the higher levels of mercury prevent regular safe consumption of fish. OEHHA encourages consumers to select fish for consumption that can be safely eaten at least once a week and that contain higher levels of omega-3 fatty acids. Typically, these species include river-run salmon and trout, and for women over 45 and men only, black bass including largemouth, smallmouth, and spotted bass. To obtain adequate levels of omega-3 fatty acids, especially at water bodies with limited or no species that can be eaten one or more times a week, consumers are advised to maintain regular consumption of fish by eating sport fish from other water bodies with less restrictive advice, or low-mercury commercial fish that are high in omega-3 fatty acids from stores or restaurants (including salmon, trout, herring, and sardines), in order to obtain the health benefits from fish consumption. Newer safe eating guidelines from OEHHA indicate fish species with high omega-3 levels.

It is very important to note that, if an individual consumes multiple species or catches fish from more than one location with an advisory, the recommended guidelines for different species and locations should not be combined (*i.e.*, added). If a person eats six ounces of cooked fish with a recommendation of one serving a week, no other fish should be eaten that week. An individual can eat one species of fish one week, and the same or a different species from the one-serving category the next week. When the recommended consumption is two, three or more servings a week, fish species in that category can be interchanged, but not added to consumption of a species from the one-serving-a-week category. River-run or ocean salmon and trout are among the best choices for all consumers because they are very low in mercury and high in omega-3 fatty acids. Regular consumption of these salmon and trout by pregnant women can confer neurological advantages to the developing fetus (Oken et al., 2005; Cohen, et al., 2005). Women 18-45 years and children 1-17 years must be careful when choosing salmon and large trout from reservoirs, however, as salmon and large trout residing in a mercury-rich reservoir environment such as Folsom Lake may accumulate high levels of mercury, similar to bass species.

OEHHA also recommends that women 18-45 and children 1-17 follow the Joint Federal Advisory for Mercury in Fish for commercial fish (U.S. EPA, 2004, see http://www.epa.gov/waterscience/fishadvice/advice.html). This advisory recommends that these individuals do not eat shark, swordfish, king mackerel, or tilefish[1] because of the high levels of mercury in these species. The federal advisory also states that these individuals can safely eat up to two meals (12 ounces cooked) of a variety of other fish purchased at stores or restaurants such as shrimp, canned light tuna, wild salmon, pollock, or (farm-raised) catfish. Albacore ("white") tuna is known to contain more mercury than canned light tuna; it is therefore recommended that no more than six ounces of albacore tuna (*e.g.*, one six-ounce can) be consumed per week.

For fish consumers who only eat sport fish occasionally, for example, on an annual vacation, consumption of a relatively high mercury species such as Chinook salmon or largemouth bass from the Folsom Lake or Lake Natoma would not be a cause for concern provided their other fish intake did not include regular consumption of high-mercury commercial fish.

For general advice on how to limit your exposure to chemical contaminants in sport fish (*e.g.*, eating smaller fish of legal size), as well as a fact sheet on methylmercury in sport fish, see the California Sport Fish Consumption Advisories (http://www.oehha.ca.gov/fish.html) and Appendices 1 and 2. Unlike the case for many fat-soluble chlorinated hydrocarbon contaminants (*e.g.*, DDTs and PCBs), however, various cooking and cleaning techniques will not reduce the methylmercury content of fish. Additionally, there are no known ways to prepare fish (such as soaking in milk) that will reduce the methylmercury content of the fish. Meal sizes should be

[1] King mackerel and tilefish are common on the east coast but rarely found in California or other western states, whereas shark and swordfish are more commonly available on the west coast.

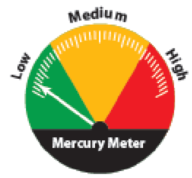
adjusted to body weight. Consumers weighing less than 160 pounds should eat smaller portions than the standard eight-ounce portion (equal to six ounces after cooking), and children should also eat smaller portions, about half as much as adults for children up to the age of 12. The complete recommendations for consumption of fish from the Folsom Lake and Lake Natoma for women 18-45 years and children 1-17 years, and for women over 45 years and men are presented below.

Guide to Eating Fish Caught in

Folsom Lake and Lake Natoma

A guide to eating fish caught in Folsom Lake and Lake Natoma

Women 18 - 45, especially those who are pregnant or breastfeeding, and children 1 - 17



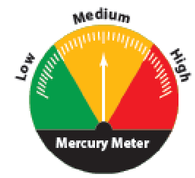
Trout ♥
16 inches long or less

Bluegill

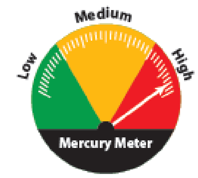
Green Sunfish and Other Sunfish

♥ = High in Omega-3s

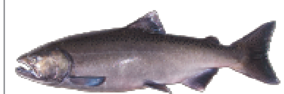
Safe to eat 2 servings per week



There are no fish with medium levels of mercury



Largemouth, Smallmouth, and Spotted Bass



Chinook (King) Salmon

Catfish

Trout
over 16 inches long

Do not eat

Men over 17 and women over 45 can safely eat more fish

- **Safe to eat 5 servings per week**
- There are no fish with medium levels of mercury
- **Safe to eat 1 serving per week** except catfish from Lake Natoma — DO NOT EAT

♥ Why eat fish?

Eating fish is good for your health. Fish have Omega-3s that can reduce your risk for heart disease and improve how the brain develops in unborn babies and children.

What is the concern?

Some fish have high levels of mercury that can negatively affect how the brain develops in unborn babies and children.

What is a serving?

For Adults For Children

The recommended serving of fish is about the size and thickness of your hand. Give children smaller servings.

Fish buying guidelines for women 18 – 45 and children 1 – 17

Do not eat fish caught by family and friends in the same week that you eat fish bought in a store or restaurant. For fish that you buy:

- **Safe to eat 2 servings per week** of low mercury fish such as salmon ♥, pollock, catfish, tilapia, shrimp, anchovies ♥, sardines ♥, trout ♥, and canned chunk-light tuna

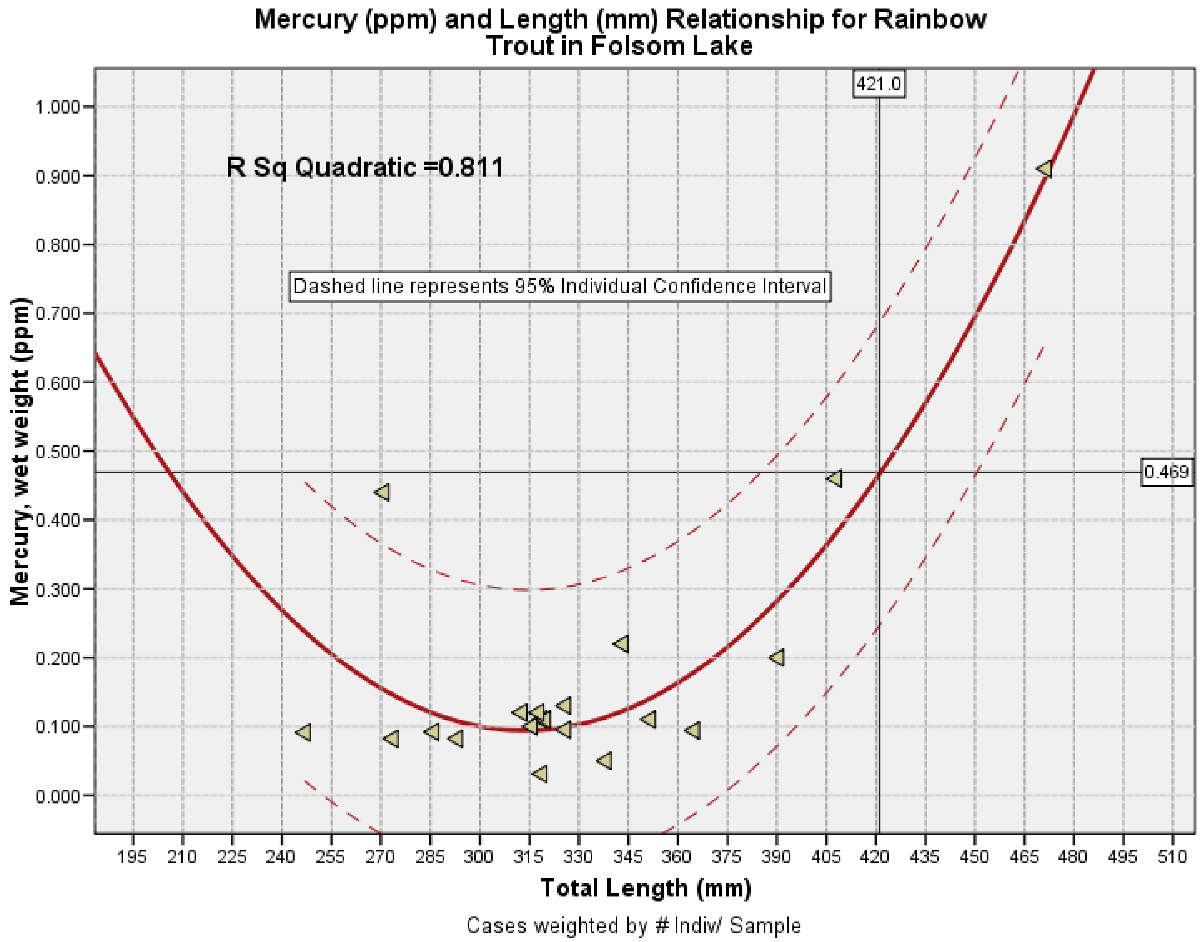
OR

- **Safe to eat 1 serving per week** of medium-mercury fish such as canned albacore (white) tuna ♥
- **Do not eat** shark, swordfish, tilefish, or king mackerel

California Office of Environmental Health Hazard Assessment
www.oehha.ca.gov/fish.html
(916) 327-7319 or (510) 622-3170

FIGURE 1. Folsom Lake and Lake Natoma

Figure 2. Relationship between Mercury and length for Rainbow Trout in Folsom Lake



The line on the graph is incorrectly labeled at 0.469 ppm. It should be 0.44 ppm.

Table 1. Overall mean mercury (Hg) concentrations and lengths of fish from Folsom Lake[1]			
	Hg (ppm, wet weight)	Length (mm)[2]	Number of Fish
Bluegill	0.12	152	11
Channel Catfish	0.51	624	10
Chinook Salmon	0.54	390	11
Green Sunfish	0.33	174	1
Largemouth Bass	0.71	407	6
Rainbow Trout			
16 inches long or less	0.13	317	18
Over 16 inches long	0.69	440	2
Smallmouth Bass	0.51	331	1
Spotted Bass	0.71	393	16
White Catfish	1.00	343	1

[1]Excludes fish below the following legal or edible size limits:

Bluegill or sunfish: 100 mm
Rainbow trout: 200 mm
Largemouth, smallmouth bass or spotted bass: 305 mm
White catfish: 200 mm
Channel catfish: 200 mm

[2]Raw data was obtained as fork length (the length from the tip of the nose/mouth to the center of the fork in the caudal fin). All fish, except Chinook salmon (which were measure as total length), were converted to total length (the longest length from the tip of the tail fin to the tip of nose/mouth), using the equation:

total length = fork length x OEHHA conversion factor

The OEHHA conversion factor for bluegill is 1.05; rainbow trout, 1.025; channel catfish, 1.15; green sunfish, 1.025; largemouth bass, 1.05, smallmouth bass, 1.05; spotted bass, 1.05; white catfish, 1.1.

Table 2. Overall Mean Mercury (Hg) Concentrations and Lengths of Fish from Lake Natoma [1]			
	Hg (ppm, wet weight)	Length (mm)[2]	Number of Fish
Black Bullhead	0.145	214	1
Bluegill	0.086	126	78
Brown Bullhead	0.353	317	1
Channel Catfish	1.474	635	11
Green Sunfish	0.135	131	3
Largemouth Bass	0.569	387	23
Rainbow Trout	0.020	324	1
Redear Sunfish	0.100	145	11
Spotted Bass	0.407	335	1
White Catfish	0.560	249	1

[1] Excludes fish below the following legal or edible size limits (mm):
Black Bullhead: 170
Bluegill: 100
Brown Bullhead: 200
Channel Catfish: 200
Green Sunfish: 100
Largemouth Bass: 305
Rainbow Trout: 200
Redear Sunfish: 130
Smallmouth Bass: 305
Spotted Bass: 305
White Catfish: 200

[2] Length was measured as total length—longest length from tip of tail fin to tip of nose/mouth. Average total lengths of fish are presented in Table 1.

Table 3. Advisory Tissue Levels for Mercury (ppm total mercury or methylmercury* wet weight) for Two Population Groups		
Population Group:	**Women 18-45 years and children 1-17 years**	**Women over 45 years and men**
Reference Dose (RfD):	**1 x 10^{-4} mg/kg-day**	**3 x 10^{-4} mg/kg-day**
8-Ounce Meals per Week	**Tissue Concentration (ppm)**	
3	≤0.07	≤0.22
2	>0.07 – 0.15	>0.22 – 0.44
1	>0.15 – 0.44	>0.44 – 1.3
Do Not Eat	>0.44	>1.3

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table, they should also first be rounded to the second significant digit as in this table.

*The values in this table are based on the assumption that 100 percent of total mercury measured in fish is methylmercury. This may not be true for shellfish, so methylmercury needs to be measured directly in these species for use in this table.

The recommended level for consumption of fish contaminated with a non-carcinogenic chemical such as methylmercury or PCBs is below or equivalent to the chemical's reference level. People could eat more fish with a lower tissue concentration (before they exceed the reference level) than fish with a higher concentration. The following general equation can be used to calculate the fish tissue concentration (in mg/kg) at which the consumption exposure from a chemical with a non-carcinogenic effect is equal to the reference level for that chemical at any consumption level:

$$\text{Tissue concentration} = \frac{(\text{RfD mg/kg - day})(\text{kg Body Weight})(\text{RSC})}{\text{CR kg/day}}$$

where,

RfD = Chemical specific reference dose or other health reference value
BW = Body weight of consumer
RSC = Relative source contribution of fish to total exposure
CR = Consumption rate as the daily amount of fish consumed

There is an almost unlimited number of potential meal frequency categories with which to provide fish consumption advice, ranging from 0.5 meals per month, or less, to one meal per day (30 meals per month) or more. OEHHA considers it reasonable to provide advice for the consumption frequency categories shown in the table including: low contaminant fish that are safe to eat in quantities meeting the American Heart Association (AHA, 2008) and the Institute of Medicine (IOM, 2007) recommendations (eight ounces per week, prior to cooking); very low contaminant fish that are safe to eat in even higher quantities (two or three eight-ounce, prior to cooking, meals a week); and higher contaminant fish whose consumption should be avoided (*i.e.*, fish that should not be consumed or cannot be eaten in quantities meeting AHA and IOM recommendations).

The equation above was applied in the table to determine tissue concentrations of methylmercury (assuming 100% of measured total mercury is methylmercury in fish) in sport fish that would be below or equivalent to the chemical's reference level for multiple consumption frequencies. ATLs for four, five, six, and seven servings per week can be calculated, as in Klasing and Brodberg (2008), using consumption rates of 128, 160, 192, and 224 g/d, respectively. As explained in Klasing and Brodberg (2008), OEHHA may also combine consumption categories to simplify consumption advice for communication.

Meal sizes and frequencies used in this table: Although people eat different meal sizes, their typical portion size is related to their individual body weight in a fairly consistent manner. The standard portion size eaten by an average adult (body weight 70 kg or 154 pounds) is eight ounces (227 g) (U.S. EPA, 2000b). A standard portion of one fish meal a week is equivalent to 0.324 kg/day, two meals per week is equivalent to 0.064.8 kg/day, and three meals per week is equivalent to 0.973 kg/day. In some cases, fish tissue concentrations corresponding to intermediate meal frequencies were incorporated into the standard meal categories used for providing fish consumption advice such that the hazard quotient (the ratio of exposure to the RfD) did not exceed an average of approximately 1, over the range of exposures.

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Appendix 1: Methylmercury in Sport Fish: Information for Fish Consumers

Methylmercury is a form of mercury that is found in most freshwater and saltwater fish. In some lakes, rivers, and coastal waters in California, methylmercury has been found in some types of fish at concentrations that may be harmful to human health. The Office of Environmental Health Hazard Assessment (OEHHA) has issued health advisories to fishers and their families giving recommendations on how much of the affected fish in these areas can be safely eaten. In these advisories, women ages 18-45 and children are encouraged to be especially careful about following the advice because of the greater sensitivity of fetuses and children to methylmercury.

Fish are nutritious and should be a part of a healthy, balanced diet. As with many other kinds of food, however, it is prudent to consume fish in moderation. OEHHA provides advice to the public so that people can continue to eat fish without putting their health at risk.

WHERE DOES METHYLMERCURY IN FISH COME FROM?

Methylmercury in fish comes from mercury in the aquatic environment. Mercury, a metal, is widely found in nature in rock and soil, and is washed into surface waters during storms. Mercury evaporates from rock, soil, and water into the air, and then falls back to the earth in rain, often far from where it started. Human activities redistribute mercury and can increase its concentration in the aquatic environment. The coastal mountains in northern California are naturally rich in mercury in the form of cinnabar ore, which was processed to produce quicksilver, a liquid form of inorganic mercury. This mercury was taken to the Sierra Nevada, Klamath mountains, and other regions, where it was used in gold mining. Historic mining operations and the remaining tailings from abandoned mercury and gold mines have contributed to the release of large amounts of mercury into California's surface waters. Mercury can also be released into the environment from industrial sources, including the burning of fossil fuels and solid wastes, and disposal of mercury-containing products.

Once mercury gets into water, much of it settles to the bottom where bacteria in the mud or sand convert it to the organic form of methylmercury. Fish absorb methylmercury when they eat smaller aquatic organisms. Larger and older fish absorb more methylmercury as they eat other fish. In this way, the amount of methylmercury builds up as it passes through the food chain. Fish eliminate methylmercury slowly, and so it builds up in fish in much greater concentrations than in the surrounding water. Methylmercury generally reaches the highest levels in predatory fish at the top of the aquatic food chain.

HOW MIGHT I BE EXPOSED TO METHYLMERCURY?

Eating fish is the main way that people are exposed to methylmercury. Each person's exposure depends on the amount of methylmercury in the fish that they eat and how much and how often they eat fish.

Women can pass methylmercury to their babies during pregnancy, and this includes methylmercury that has built up in the mother's body even before pregnancy. For this reason, women aged 18-45 are encouraged to be especially careful to follow consumption advice, even if they are not pregnant. In addition, nursing mothers can pass methylmercury to their child through breast milk.

You may be exposed to inorganic forms of mercury through dental amalgams (fillings) or accidental spills, such as from a broken thermometer. For most people, these sources of exposure to mercury are minor and of less concern than exposure to methylmercury in fish.

AT WHAT LOCATIONS IN CALIFORNIA HAVE ELEVATED LEVELS OF MERCURY BEEN FOUND IN FISH?

Methylmercury is found in most fish, but some fish and some locations have higher amounts than others. Methylmercury is one of the chemicals in fish that most often creates a health concern. Consumption advisories due to high levels of methylmercury in fish have been issued in about 40 states. In California, methylmercury advisories have been issued for San Francisco Bay and the Delta; Tomales Bay in Marin County; and at the following inland lakes: Lake Nacimiento in San Luis Obispo County; Lake Pillsbury and Clear Lake in Lake County; Lake Berryessa in Napa County; Guadalupe Reservoir and associated reservoirs in Santa Clara County; Lake Herman in Solano County; San Pablo Reservoir in Contra Costa County; Black Butte Reservoir in Glenn and Tehama Counties; Lake Natoma and the lower American River in Sacramento County; Trinity Lake in Trinity County; and certain lakes and river stretches in the Sierra Nevada foothills in Nevada, Placer, and Yuba counties. Other locations may be added in the future as more fish and additional water bodies are tested.

HOW DOES METHYLMERCURY AFFECT HEALTH?

Much of what we know about methylmercury toxicity in humans stems from several mass poisoning events that occurred in Japan during the 1950s and 1960s, and Iraq during the 1970s. In Japan, a chemical factory discharged vast quantities of mercury into several bays near fishing villages. Many people who consumed large amounts of fish from these bays became seriously ill or died over a period of several years. In Iraq, thousands of people were poisoned by eating contaminated bread that was mistakenly made from seed grain treated with methylmercury.

From studying these cases, researchers have determined that the main target of methylmercury toxicity is the central nervous system. At the highest exposure levels experienced in these poisonings, methylmercury toxicity symptoms included such nervous system effects as loss of coordination, blurred vision or blindness, and hearing and speech impairment. Scientists also discovered that the developing nervous systems of fetuses are particularly sensitive to the toxic effects of methylmercury. In the Japanese outbreak, for example, some fetuses developed methylmercury toxicity during pregnancy even when their mothers did not. Symptoms reported in the Japan and Iraq epidemics resulted from methylmercury levels that were much higher than what fish consumers in the U.S. would experience.

Individual cases of adverse health effects from heavy consumption of commercial fish containing moderate to high levels of methylmercury have been reported only rarely. Nervous system symptoms reported in these instances included headaches, fatigue, blurred vision, tremor, and/or some loss of concentration, coordination, or memory. However, because there was no clear link between the severity of symptoms and the amount of mercury to which the person was exposed, it is not possible to say with certainly that these effects were a consequence of methylmercury exposure and not the result of other health problems. The most subtle symptoms in adults known to be clearly associated with methylmercury toxicity are numbness or tingling in the hands and feet or around the mouth; however, these symptoms are also associated with other medical conditions not related to methylmercury exposure.

In recent studies of high fish-eating populations in different parts of the world, researchers have been able to detect more subtle effects of methylmercury toxicity in children whose mothers frequently ate seafood containing low to moderate mercury concentrations during their pregnancy. Several studies found slight decreases in learning ability, language skills, attention and/or memory in some of these children. These effects were not obvious without using very specialized and sensitive tests. Children may have increased susceptibility to the effects of methylmercury through adolescence, as the nervous system continues to develop during this time.

Methylmercury builds up in the body if exposure continues to occur over time. Exposure to relatively high doses of methylmercury for a long period of time may also cause problems in other organs such as the kidneys and heart.

CAN MERCURY POISONING OCCUR FROM EATING SPORT FISH IN CALIFORNIA?

No case of mercury poisoning has been reported from eating California sport fish. The levels of mercury in California fish are much lower than those that occurred during the Japanese outbreak. Therefore, overt poisoning resulting from sport fish consumption in California would not be expected. At the levels of mercury found in California fish, symptoms associated with methylmercury are unlikely unless someone eats much more than what is recommended or is particularly sensitive. The fish consumption guidelines are designed to protect against subtle effects that would be difficult to detect but could still occur FOLLOWING unrestricted consumption of California sport fish. This is especially true in the case of fetuses and children.

IS THERE A WAY TO REDUCE METHYLMERCURY IN FISH TO MAKE THEM SAFER TO EAT?

There is no specific method of cleaning or cooking fish that will significantly reduce the amount of methylmercury in the fish. However, fish should be cleaned and gutted before cooking because some mercury may be present in the liver and other organs of the fish. These organs should not be eaten.

In the case of methylmercury, fish size is important because large fish that prey upon smaller fish can accumulate more of the chemical in their bodies. It is better to eat the smaller fish within the same species, provided that they are legal size.

IS THERE A MEDICAL TEST TO DETERMINE EXPOSURE TO METHYLMERCURY?

Mercury in blood and hair can be measured to assess methylmercury exposure. However, this is not routinely done. Special techniques in sample collection, preparation, and analysis are required for these tests to be accurate. Although tests using hair are less invasive, they are also less accurate. It is important to consult with a physician before undertaking medical testing because these tests alone cannot determine the cause of personal symptoms.

HOW CAN I REDUCE THE AMOUNT OF METHYLMERCURY IN MY BODY?

Methylmercury is eliminated from the body over time provided that the amount of mercury taken in is reduced. Therefore, following the OEHHA consumption advice and eating less of the fish that have higher levels of mercury can reduce your exposure and help to decrease the levels of methylmercury already in your body if you have not followed these recommendations in the past.

WHAT IF I EAT FISH FROM OTHER SOURCES SUCH AS RESTAURANTS, STORES, OR OTHER WATER BODIES THAT MAY NOT HAVE AN ADVISORY?

Most commercial fish have relatively low amounts of methylmercury and can be eaten safely in moderate amounts. However, several types of fish such as large, predatory, long-lived fish have high levels of methylmercury, and could cause overly high exposure to methylmercury if eaten often. The U.S. Food and Drug Administration (FDA) is responsible for the safety of commercial seafood. In 2004, FDA and the U.S. Environmental Protection Agency (U.S. EPA) issued a Joint Federal Advisory for Mercury in Fish advising women who are pregnant or could become pregnant, nursing mothers, and young children not to eat shark, swordfish, king mackerel, or tilefish. The federal advisory also recommends that these individuals can safely eat up to an average of 12 ounces (two average meals) per week of a variety of other cooked fish purchased in stores or restaurants, such as shrimp, canned light tuna, salmon, pollock, or (farm-raised) catfish. Albacore ("white") tuna is known to contain more mercury than canned light tuna; it is therefore recommended that no more than six ounces of albacore tuna be consumed per week. In addition, the federal advisory recommends that women who are pregnant or may become pregnant, nursing mothers, and young children consume no more than one meal per week of locally caught fish, when no other advice is available, and eat no other fish that week. The federal advisory can be found at http://www.cfsan.fda.gov/~dms/admehg.html or http://www.epa.gov/ost/fishadvice/advice.html.

In addition, OEHHA offers the following general advice that can be followed to reduce exposure to methylmercury in fish. Chemical levels can vary from place to place. Therefore, your overall exposure to chemicals is likely to be lower if you fish at a variety of places, rather than at one location that might have high contamination levels. Furthermore, some fish species have higher chemical levels than others in the same location. If possible, eat smaller amounts of several different types of fish rather than a large amount of one type that may be high in contaminants. Smaller fish of a species will usually have lower chemical levels than larger fish in the same location because some of the chemicals may become more concentrated in larger, older fish. It is advisable to eat smaller fish (of legal size) more often than larger fish. Cleaning and cooking fish in a manner that removes fat and organs is an effective way to reduce other contaminants that may be present in fish.

WHERE CAN I GET MORE INFORMATION?

The health advisories for sport fish are printed in the California Sport Fishing Regulations booklet, which is available wherever fishing licenses are sold. OEHHA also offers a booklet containing the advisories, and additional materials such as this fact sheet on related topics. Additional information and documents related to fish advisories are available on the OEHHA Web Site at http://www.oehha.ca.gov/fish.html. County departments of environmental health may have more information on specific fishing areas.

Appendix 2. General Advice for Sport Fish Consumers

You can reduce your exposure to chemical contaminants in sport fish by following the recommendations below. Follow as many of them as you can to increase your health protection. This general advice is not meant to take the place of advisories for specific areas, but should be followed in addition to them. Sport fish in most water bodies in the state have not been evaluated for their safety for human consumption. This is why we strongly recommend following the general advice given below.

Fishing Practices

Chemical levels can vary from place to place. Your overall exposure to chemicals is likely to be lower if you eat fish from a variety of places rather than from one usual spot that might have high contamination levels.

Be aware that OEHHA may issue new advisories or revise existing ones. Consult the Department of Fish and Game regulations booklet or check with OEHHA on a regular basis to see if there are any changes that could affect you.

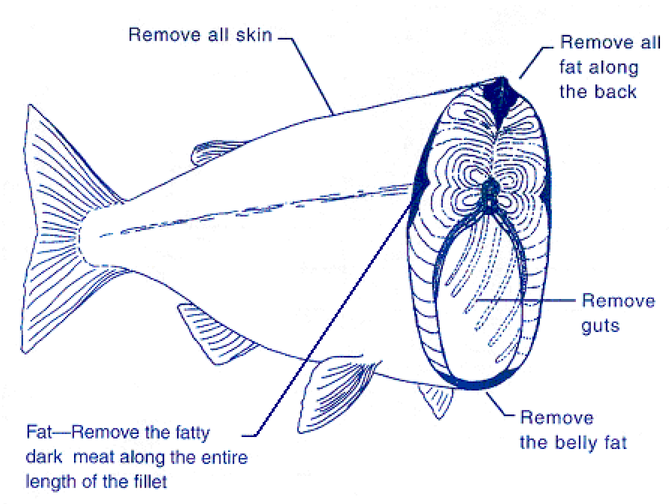
Consumption Guidelines

Fish Species: Some fish species have higher chemical levels than others in the same location. If possible, eat smaller amounts of several different types of fish rather than a large amount of one type that may be high in contaminants.

Fish Size: Smaller fish of a species will usually have lower chemical levels than larger fish in the same location because some of the chemicals may accumulate as the fish grows. It is advisable to eat smaller fish (of legal size).

Fish Preparation and Consumption

- Eat only the fillet portions. Do not eat the guts and liver because chemicals usually concentrate in those parts. Also, avoid frequent consumption of any reproductive parts such as eggs or roe.
- Many chemicals are stored in the fat. To reduce the levels of these chemicals, skin the fish when possible and trim any visible fat.
- Use a cooking method such as baking, broiling, grilling, or steaming that allows the juices to drain away from the fish. The juices will contain chemicals in the fat and should be thrown away. Preparing and cooking fish in this way can remove 30 to 50 percent of the chemicals stored in fat. If you make stews or chowders, use fillet parts.
- Raw fish may be infested by parasites. Cook fish thoroughly to destroy the parasites.



Advice for Women 18-45 Years, Including Pregnant and Breastfeeding Women, and Children

Children and fetuses are more sensitive to the toxic effects of methylmercury, the form of mercury of health concern in fish. For this reason, OEHHA's advisories that are based on mercury provide special advice for women 18-45 years and children. Women should follow this advice throughout their childbearing years.

The U.S. Food and Drug Administration (FDA) is responsible for the safety of commercial seafood. Most commercial fish have relatively low amounts of methylmercury and can be eaten safely in moderate amounts. However, several types of fish such as large, predatory, long-lived fish have high levels of methylmercury, and could cause overly high exposure to methylmercury if eaten often. In 2004, FDA and the U.S. Environmental Protection Agency (U.S. EPA) issued a Joint Federal Advisory for Mercury in Fish advising women who are pregnant or could become pregnant, nursing mothers, and young children not to eat shark, swordfish, king mackerel, or tilefish. The federal advisory also recommends that these individuals can safely eat up to an average of 12 ounces (two average meals) per week of a variety of other cooked fish purchased in stores or restaurants, such as shrimp, canned light tuna, salmon, pollock, or (farm-raised) catfish. Albacore ("white") tuna is known to contain more than FDA has issued the following advice about the risks of mercury in fish to pregnant women and women who may become pregnant. FDA advises these women not to eat shark, swordfish, king mackerel, or tilefish. FDA also advises that it is prudent for nursing mothers and young children not to eat these fish as well.

The U.S. Environmental Protection Agency has also issued national advice to protect women who are pregnant or may become pregnant, nursing mothers, and young children against consuming excessive mercury in fish. They recommend that these individuals eat no more than one meal per week of non-commercial freshwater fish caught by family and friends.

National advice for women and children on mercury in fish is available from the U.S. Environmental Protection Agency at www.epa.gov/waterscience/fishadvice/advice.html and the U.S. Food and Drug Administration at www.cfsan.fda.gov/~dms/admehg.html

Appendix 3. Descriptive Statistics for Mercury Concentrations and Length for Legal/Edible-Sized Fish from Folsom Lake

Species	**Mean Mercury (ppm, wet)**	*Median*	*SD*	*Min*	*Max*	**Mean Length[1] (mm)**	*Median*	*SD*	*Min*	*Max*	**# Samples**	**# Indiv**
Bluegill Sunfish	**.12**	.095	.039	.071	.180	**151.6**	144.9	18.0	131.3	189.0	11	11
Channel Catfish	**.51**	.505	.077	.370	.650	**624.0**	614.1	69.5	529.0	736.0	10	10
Chinook Salmon	**.54**	.450	.267	.042	1.00	**390.0** [1]	325.5 [1]	107.5	288.8	566.8	11	11
Green Sunfish	**.33**	.330	[2]	.330	.330	**174.3**	174.3	[2]	174.3	174.3	1	1
Largemouth Bass	**.71**	.670	.205	.470	.980	**406.9**	378.0	74.2	336.0	540.8	6	6
Rainbow Trout	**.18**	.110	.205	.031	.910	**329.7**	319.3	51.1	247.0	471.5	20	20
Smallmouth Bass	**.51**	.510	[2]	.510	.510	**330.8**	330.8	[2]	330.8	330.8	1	1
Spotted Bass	**.71**	.680	.253	.360	1.20	**393.3**	399.0	51.5	325.5	498.8	16	16
White Catfish	**1.00**	1.00	[2]	1.00	1.00	**343.2**	343.2	[2]	343.2	343.2	1	1

[1] Samples reported fork length only. Average lengths of fish presented in Appendix 3 are type=total length (Fork Length *times* OEHHA conversion factor) except for Chinook salmon where total length (TL) was measured and no conversion was necessary. The OEHHA conversion factor for Bluegill is 1.05, for Channel Catfish 1.15, for Green Sunfish 1.025, for Largemouth Bass 1.05, for Rainbow Trout 1.025, for Smallmouth Bass 1.05, for Spotted Bass 1.05, and for White Catfish 1.1

[2] Standard Deviation is omitted because Hg ppm and Length mm are constant.

Appendix 4: Mercury Values of Individual Fish Tissue Samples of Legal/Edible Size from Folsom Lake

All Samples Meet OEHHA Size Criteria

Project	Mercury ppm (wet weight)	Date	Common Name	# Indiv/ Sample	Fork Length mm	Total Length[1] mm
USBR	**0.090**	07/29/2004	Bluegill Sunfish	1	125.0	131.3
USBR	**0.071**	08/04/2006	Bluegill Sunfish	1	127.0	133.4
USBR	**0.076**	08/04/2006	Bluegill Sunfish	1	128.0	134.4
USBR	**0.160**	08/04/2006	Bluegill Sunfish	1	136.0	142.8
USBR	**0.150**	08/04/2006	Bluegill Sunfish	1	137.0	143.9
USBR	**0.086**	08/04/2006	Bluegill Sunfish	1	138.0	144.9
USBR	**0.091**	08/04/2006	Bluegill Sunfish	1	143.0	150.2
USBR	**0.095**	08/04/2006	Bluegill Sunfish	1	156.0	163.8
USBR	**0.140**	08/04/2006	Bluegill Sunfish	1	158.0	165.9
USBR	**0.150**	08/04/2006	Bluegill Sunfish	1	160.0	168.0
USBR	**0.180**	07/29/2004	Bluegill Sunfish	1	180.0	189.0
USBR	**0.510**	07/29/2004	Channel Catfish	1	460.0	529.0
USBR	**0.560**	07/29/2004	Channel Catfish	1	480.0	552.0
USBR	**0.590**	07/29/2004	Channel Catfish	1	484.0	556.6
USBR	**0.370**	07/29/2004	Channel Catfish	1	514.0	591.1
USBR	**0.500**	07/29/2004	Channel Catfish	1	528.0	607.2
USBR	**0.510**	07/29/2004	Channel Catfish	1	540.0	621.0
USBR	**0.650**	07/29/2004	Channel Catfish	1	580.0	667.0
USBR	**0.450**	07/29/2004	Channel Catfish	1	590.0	678.5
USBR	**0.490**	07/29/2004	Channel Catfish	1	610.0	701.5
USBR	**0.470**	07/29/2004	Channel Catfish	1	640.0	736.0
USBR	**0.470**	08/06/2004	Chinook Salmon	1	440.0	.
USBR	**1.000**	08/06/2004	Chinook Salmon	1	500.0	.
USBR	**0.850**	08/06/2004	Chinook Salmon	1	520.0	.
USBR	**0.810**	08/17/2004	Chinook Salmon	1	553.0	.
USBR	**0.390**	02/20/2007	Chinook Salmon	1	280.0	.
USBR	**0.440**	02/20/2007	Chinook Salmon	1	275.0	.
USBR	**0.430**	02/20/2007	Chinook Salmon	1	295.0	.
USBR	**0.650**	02/20/2007	Chinook Salmon	1	380.0	.
USBR	**0.410**	02/20/2007	Chinook Salmon	1	305.0	.
USBR	**0.042**	02/20/2007	Chinook Salmon	1	276.0	.
USBR	**0.450**	02/20/2007	Chinook Salmon	1	310.0	.
USBR	**0.330**	07/29/2004	Green Sunfish	1	170.0	174.3
USBR	**0.600**	07/29/2004	Largemouth Bass	1	320.0	336.0
USBR	**0.470**	07/29/2004	Largemouth	1	350.0	367.5

Project	Mercury ppm (wet weight)	Date	Common Name	# Indiv/ Sample	Fork Length mm	Total Length[1] mm
			Bass			
USBR	**0.560**	07/29/2004	Largemouth Bass	1	350.0	367.5
USBR	**0.980**	07/29/2004	Largemouth Bass	1	370.0	388.5
USBR	**0.920**	07/29/2004	Largemouth Bass	1	420.0	441.0
USBR	**0.740**	07/29/2004	Largemouth Bass	1	515.0	540.8
USBR	**0.091**	06/17/2006	Rainbow Trout	1	241.0	247.0
USBR	**0.440**	02/20/2007	Rainbow Trout	1	263.0	.
USBR	**0.082**	06/17/2006	Rainbow Trout	1	267.0	273.7
USBR	**0.092**	06/17/2006	Rainbow Trout	1	279.0	286.0
USBR	**0.082**	06/17/2006	Rainbow Trout	1	286.0	293.2
USBR	**0.120**	06/17/2006	Rainbow Trout	1	305.0	312.6
USBR	**0.100**	08/17/2004	Rainbow Trout	1	308.0	315.7
USBR	**0.120**	08/06/2004	Rainbow Trout	1	310.0	317.8
USBR	**0.031**	06/17/2006	Rainbow Trout	1	311.0	318.8
USBR	**0.110**	06/17/2006	Rainbow Trout	1	311.0	318.8
USBR	**0.110**	08/18/2004	Rainbow Trout	1	312.0	319.8
USBR	**0.095**	06/17/2006	Rainbow Trout	1	318.0	326.0
USBR	**0.130**	06/17/2006	Rainbow Trout	1	318.0	326.0
USBR	**0.050**	06/17/2006	Rainbow Trout	1	330.0	338.3
USBR	**0.220**	08/18/2004	Rainbow Trout	1	335.0	343.4
USBR	**0.110**	06/17/2006	Rainbow Trout	1	343.0	351.6
USBR	**0.094**	06/17/2006	Rainbow Trout	1	356.0	364.9
USBR	**0.200**	06/17/2006	Rainbow Trout	1	381.0	390.5
USBR	**0.460**	08/17/2004	Rainbow Trout	1	398.0	408.0
USBR	**0.910**	08/17/2004	Rainbow Trout	1	460.0	471.5
USBR	**0.510**	07/29/2004	Smallmouth Bass	1	315.0	330.8
USBR	**0.380**	07/29/2004	Spotted Bass	1	310.0	325.5
USBR	**0.380**	07/29/2004	Spotted Bass	1	310.0	325.5
USBR	**0.360**	07/29/2004	Spotted Bass	1	320.0	336.0
USBR	**0.590**	07/29/2004	Spotted Bass	1	325.0	341.3
USBR	**0.430**	07/29/2004	Spotted Bass	1	330.0	346.5
USBR	**0.560**	07/29/2004	Spotted Bass	1	360.0	378.0
USBR	**0.650**	07/29/2004	Spotted Bass	1	360.0	378.0
USBR	**0.710**	07/29/2004	Spotted Bass	1	380.0	399.0
USBR	**0.800**	07/29/2004	Spotted Bass	1	380.0	399.0
USBR	**1.000**	07/29/2004	Spotted Bass	1	380.0	399.0
USBR	**0.640**	07/29/2004	Spotted Bass	1	385.0	404.3

Project	Mercury ppm (wet weight)	Date	Common Name	# Indiv/ Sample	Fork Length mm	Total Length[1] mm
USBR	**0.830**	07/29/2004	Spotted Bass	1	395.0	414.8
USBR	**0.980**	06/17/2006	Spotted Bass	1	413.0	433.7
USBR	**0.870**	07/29/2004	Spotted Bass	1	420.0	441.0
USBR	**0.940**	07/29/2004	Spotted Bass	1	450.0	472.5
USBR	**1.200**	07/29/2004	Spotted Bass	1	475.0	498.8
USBR	**1.000**	07/29/2004	White Catfish	1	312.0	343.2

[1] Samples reported fork length only. Average lengths of fish presented in Appendix 3 are type=total length (Fork Length *times* OEHHA conversion factor) except for Chinook salmon where total length (TL). The OEHHA conversion factor for Bluegill is 1.05, for Channel Catfish 1.15, for Green Sunfish 1.025, for Largemouth Bass 1.05, for Rainbow Trout 1.025, for Smallmouth Bass 1.05, for Spotted Bass 1.05, and for White Catfish 1.1

Appendix 5. Descriptive Statistics for Mercury Concentrations and Length for Legal/Edible-Sized Fish from Lake Natoma

Species	***Mean Mercury (ppm, wet)***	*Median*	*SD*	*Min*	*Max*	***Mean Length[1] (mm)***	*Median*	*SD*	*Min*	*Max*	***# Samples***	***# Indiv***
Black Bullhead	**.145**	.145	[2]	.145	.145	**214**	214	[2]	214	214	1	1
Bluegill	**.086**	.082	.031	.041	.185	**126**	120	20	100	174	78	78
Brown Bullhead	**.353**	.353	[2]	.353	.353	**317**	317	[2]	317	317	1	1
Channel Catfish	**1.474**	1.576	.303	.960	1.887	**635**	649	75	505	750	11	11
Green Sunfish	**.135**	.111	.053	.098	.196	**131**	126	18	115	151	3	3
Largemouth Bass	**.569**	.577	.173	.268	.920	**387**	385	47	315	490	23	23
Rainbow Trout	**.020**	.020	[2]	.020	.020	**324**	324	[2]	324	324	1	1
Redear Sunfish	**.100**	.061	.104	.028	.388	**145**	141	16	129	187	11	11
Spotted Bass	**.407**	.407	[2]	.407	.407	**335**	335	[2]	335	335	1	1
White Catfish	**.560**	.560	[2]	.560	.560	**249**	249	[2]	249	249	1	1

[1] Fish length is reported as total length.

[2] Standard Deviation is omitted because Hg ppm and Length mm are constant.

Appendix 6: Mercury Values of Individual Fish Tissue Samples of Legal/Edible Size from Lake Natoma

Common Name	Source	Year	Station	#	Total Length mm[1]	Mercury Wet (ug/g)
Black Bullhead	USGS	2002	Willow Creek	1	214	**.145**
Bluegill	USGS	2002	Mississippi Bar	1	100	**.105**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	101	**.065**
Bluegill	USGS	2002	Willow Creek	1	102	**.041**
Bluegill	USGS	2002	Negro Bar	1	102	**.050**
Bluegill	USGS	2002	Negro Bar	1	102	**.075**
Bluegill	USGS	2002	Willow Creek	1	103	**.049**
Bluegill	USGS	2002	Mississippi Bar	1	103	**.093**
Bluegill	USGS	2002	Alder Creek	1	104	**.050**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	104	**.061**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	104	**.088**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	104	**.101**
Bluegill	USGS	2002	Mississippi Bar	1	105	**.058**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	105	**.061**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	105	**.065**
Bluegill	USGS	2002	Alder Creek	1	105	**.103**
Bluegill	USGS	2002	Mississippi Bar	1	106	**.053**
Bluegill	USGS	2002	Alder Creek	1	106	**.065**
Bluegill	USGS	2002	Mississippi Bar	1	106	**.098**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	107	**.063**
Bluegill	USGS	2002	Alder Creek	1	107	**.067**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	108	**.058**
Bluegill	USGS	2002	Alder Creek	1	108	**.083**
Bluegill	USGS	2002	Negro Bar	1	108	**.155**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	109	**.049**
Bluegill	USGS	2002	Willow Creek	1	110	**.068**
Bluegill	USGS	2002	Alder Creek	1	111	**.054**
Bluegill	USGS	2002	Alder Creek	1	112	**.050**
Bluegill	USGS	2002	Mississippi Bar	1	112	**.104**
Bluegill	USGS	2002	Mississippi Bar	1	113	**.088**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	114	**.064**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	114	**.068**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	115	**.080**
Bluegill	USGS	2002	Alder Creek	1	115	**.083**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	115	**.094**
Bluegill	USGS	2002	Alder Creek	1	116	**.066**
Bluegill	USGS	2002	Negro Bar	1	117	**.082**
Bluegill	USGS	2002	Alder Creek	1	119	**.066**

Common Name	Source	Year	Station	#	Total Length mm[1]	Mercury Wet (ug/g)
Bluegill	USGS	2002	Alder Creek	1	120	**.061**
Bluegill	USGS	2002	Mississippi Bar	1	120	**.073**
Bluegill	USGS	2002	Mississippi Bar	1	120	**.092**
Bluegill	USGS	2002	Mississippi Bar	1	120	**.127**
Bluegill	USGS	2002	Mississippi Bar	1	121	**.074**
Bluegill	USGS	2002	Willow Creek	1	123	**.056**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	123	**.084**
Bluegill	USGS	2002	Mississippi Bar	1	129	**.066**
Bluegill	USGS	2002	Mississippi Bar	1	129	**.068**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	131	**.058**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	131	**.150**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	133	**.051**
Bluegill	USGS	2002	Mississippi Bar	1	133	**.134**
Bluegill	USGS	2002	Alder Creek	1	135	**.062**
Bluegill	USGS	2002	Mississippi Bar	1	135	**.107**
Bluegill	USGS	2002	Mississippi Bar	1	136	**.106**
Bluegill	USGS	2002	Negro Bar	1	136	**.110**
Bluegill	USGS	2002	Mississippi Bar	1	139	**.059**
Bluegill	USGS	2002	Alder Creek	1	140	**.083**
Bluegill	USGS	2002	Alder Creek	1	140	**.093**
Bluegill	USGS	2002	Negro Bar	1	143	**.102**
Bluegill	USGS	2002	Negro Bar	1	143	**.146**
Bluegill	USGS	2002	Alder Creek	1	144	**.085**
Bluegill	USGS	2002	Negro Bar	1	148	**.063**
Bluegill	USGS	2002	Mississippi Bar	1	149	**.082**
Bluegill	USGS	2002	Mississippi Bar	1	150	**.113**
Bluegill	USGS	2002	Negro Bar	1	150	**.115**
Bluegill	USGS	2002	Negro Bar	1	151	**.066**
Bluegill	USGS	2002	Negro Bar	1	151	**.162**
Bluegill	USGS	2002	Mississippi Bar	1	152	**.055**
Bluegill	USGS	2002	Negro Bar	1	152	**.073**
Bluegill	USGS	2002	Negro Bar	1	152	**.116**
Bluegill	USGS	2002	Mississippi Bar	1	152	**.144**
Bluegill	USGS	2002	Negro Bar	1	154	**.091**
Bluegill	USGS	2002	Negro Bar	1	155	**.100**
Bluegill	USGS	2002	Mississippi Bar	1	156	**.096**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	157	**.128**
Bluegill	USGS	2002	Negro Bar	1	159	**.121**
Bluegill	USGS	2002	Willow Creek	1	160	**.140**
Bluegill	USGS	2002	Negro Bar	1	161	**.124**
Bluegill	USGS	2002	Negro Bar	1	174	**.185**
Brown Bullhead	USGS	2002	Negro Bar	1	317	**.353**

Common Name	Source	Year	Station	#	Total Length mm[1]	Mercury Wet (ug/g)
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	505	**1.610**
Channel Catfish	USGS/ UCD	2000	Natomas Slough	1	540	**.960**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	555	**1.098**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	615	**1.103**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	630	**1.785**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	649	**1.444**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	681	**1.434**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	682	**1.716**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	685	**1.601**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	690	**1.576**
Channel Catfish	USGS/ UCD	2003	Lake Natoma (Willow Ck. Inlet)	1	750	**1.887**
Green Sunfish	USGS	2002	Mississippi Bar	1	115	**.098**
Green Sunfish	USGS	2002	Mississippi Bar	1	126	**.111**
Green Sunfish	USGS	2002	Negro Bar	1	151	**.196**
Largemouth Bass	USGS	2002	Alder Creek	1	340	**.557**
Largemouth Bass	USGS	2002	Willow Creek	1	341	**.555**
Largemouth Bass	USGS	2002	Alder Creek	1	353	**.268**
Largemouth Bass	USGS	2002	Willow Creek	1	361	**.383**
Largemouth Bass	USGS	2002	Willow Creek	1	369	**.859**
Largemouth Bass	USGS	2002	Willow Creek	1	375	**.516**
Largemouth Bass	USGS	2002	Alder Creek	1	378	**.485**
Largemouth Bass	USGS	2002	Mississippi Bar	1	390	**.282**
Largemouth Bass	USGS	2002	Alder Creek	1	395	**.576**
Largemouth Bass	USGS	2002	Alder Creek	1	407	**.604**
Largemouth Bass	USGS	2002	Negro Bar	1	415	**.695**
Largemouth Bass	USGS	2002	Alder Creek	1	425	**.577**
Largemouth Bass	USGS	2002	Willow Creek	1	446	**.692**
Largemouth Bass	USGS	2002	Mississippi Bar	1	490	**.807**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	315	**.320**

Common Name	Source	Year	Station	#	Total Length mm[1]	Mercury Wet (ug/g)
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	320	**.640**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	330	**.600**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	360	**.330**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	385	**.580**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	390	**.580**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	410	**.720**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	425	**.550**
Largemouth Bass	USGS/ UCD	2002	Not listed in data source	1	480	**.920**
Rainbow Trout	USGS	2002	Nimbus Dam (DAM)	1	324	**.020**
Redear Sunfish	USGS	2002	Willow Creek	1	129	**.057**
Redear Sunfish	USGS	2002	Mississippi Bar	1	134	**.028**
Redear Sunfish	USGS	2002	Willow Creek	1	136	**.168**
Redear Sunfish	USGS	2002	Negro Bar	1	137	**.073**
Redear Sunfish	USGS	2002	Willow Creek	1	140	**.052**
Redear Sunfish	USGS	2002	Negro Bar	1	141	**.046**
Redear Sunfish	USGS	2002	Negro Bar	1	142	**.388**
Redear Sunfish	USGS	2002	Willow Creek	1	143	**.061**
Redear Sunfish	USGS	2002	Negro Bar	1	145	**.120**
Redear Sunfish	USGS	2002	Willow Creek	1	161	**.031**
Redear Sunfish	USGS	2002	Willow Creek	1	187	**.072**
Spotted Bass	USGS	2002	Nimbus Dam (DAM)	1	335	**.407**
White Catfish	USGS	2002	Negro Bar	1	249	**.560**

[1] Length was measured as total length—longest length from tip of tail fin to tip of nose/mouth.

Appendix 7: Mercury Values of Individual Fish Tissue Samples Below Legal/Edible size from Lake Natoma

Common Name	Data Source	Year	Site	#	Total Length mm[1]	Mercury Wet (ug/g)
Bluegill	USGS	2002	Willow Creek	1	72	**.114**
Bluegill	USGS	2002	Willow Creek	1	73	**.084**
Bluegill	USGS	2002	Willow Creek	1	73	**.121**
Bluegill	USGS	2002	Willow Creek	1	81	**.158**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	85	**.058**
Bluegill	USGS	2002	Alder Creek	1	90	**.098**
Bluegill	USGS	2002	Mississippi Bar	1	90	**.141**
Bluegill	USGS	2002	Negro Bar	1	91	**.091**
Bluegill	USGS	2002	Mississippi Bar	1	92	**.084**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	93	**.076**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	93	**.082**
Bluegill	USGS	2002	Negro Bar	1	95	**.056**
Bluegill	USGS	2002	Alder Creek	1	95	**.076**
Bluegill	USGS	2002	Mississippi Bar	1	95	**.083**
Bluegill	USGS	2002	Alder Creek	1	95	**.095**
Bluegill	USGS	2002	Alder Creek	1	97	**.047**
Bluegill	USGS	2002	Negro Bar	1	97	**.079**
Bluegill	USGS	2002	Negro Bar	1	98	**.104**
Bluegill	USGS	2002	Nimbus Dam (DAM)	1	99	**.094**
Green Sunfish	USGS	2002	Nimbus Dam (DAM)	1	90	**.061**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	88	**.065**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	90	**.062**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	95	**.077**
Largemouth Bass	USGS	2002	Mississippi Bar	1	105	**.098**
Largemouth Bass	USGS	2002	Mississippi Bar	1	110	**.069**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	110	**.103**

Common Name	Data Source	Year	Site	#	Total Length mm[1]	Mercury Wet (ug/g)
Largemouth Bass	USGS	2002	Alder Creek	1	117	**.096**
Largemouth Bass	USGS	2002	Negro Bar	1	132	**.111**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	139	**.122**
Largemouth Bass	USGS	2002	Negro Bar	1	149	**.133**
Largemouth Bass	USGS	2002	Willow Creek	1	150	**.135**
Largemouth Bass	USGS	2002	Alder Creek	1	151	**.127**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	153	**.092**
Largemouth Bass	USGS	2002	Mississippi Bar	1	154	**.204**
Largemouth Bass	USGS	2002	Alder Creek	1	158	**.121**
Largemouth Bass	USGS	2002	Mississippi Bar	1	159	**.101**
Largemouth Bass	USGS	2002	Negro Bar	1	159	**.130**
Largemouth Bass	USGS	2002	Negro Bar	1	164	**.099**
Largemouth Bass	USGS	2002	Willow Creek	1	164	**.152**
Largemouth Bass	USGS	2002	Negro Bar	1	169	**.149**
Largemouth Bass	USGS	2002	Willow Creek	1	169	**.246**
Largemouth Bass	USGS	2002	Willow Creek	1	173	**.169**
Largemouth Bass	USGS	2002	Alder Creek	1	178	**.133**
Largemouth Bass	USGS	2002	Negro Bar	1	179	**.167**
Largemouth Bass	USGS	2002	Negro Bar	1	181	**.118**
Largemouth Bass	USGS	2002	Negro Bar	1	181	**.192**
Largemouth Bass	USGS	2002	Alder Creek	1	188	**.215**

Common Name	Data Source	Year	Site	#	Total Length mm[1]	Mercury Wet (ug/g)
Largemouth Bass	USGS	2002	Alder Creek	1	190	**.115**
Largemouth Bass	USGS	2002	Willow Creek	1	193	**.243**
Largemouth Bass	USGS	2002	Alder Creek	1	201	**.161**
Largemouth Bass	USGS	2002	Negro Bar	1	201	**.231**
Largemouth Bass	USGS	2002	Willow Creek	1	204	**.165**
Largemouth Bass	USGS	2002	Negro Bar	1	206	**.232**
Largemouth Bass	USGS	2002	Negro Bar	1	208	**.155**
Largemouth Bass	USGS	2002	Willow Creek	1	216	**.230**
Largemouth Bass	USGS	2002	Alder Creek	1	220	**.213**
Largemouth Bass	USGS	2002	Negro Bar	1	232	**.196**
Largemouth Bass	USGS	2002	Alder Creek	1	238	**.214**
Largemouth Bass	USGS	2002	Willow Creek	1	239	**.193**
Largemouth Bass	USGS	2002	Negro Bar	1	244	**.256**
Largemouth Bass	USGS	2002	Willow Creek	1	245	**.186**
Largemouth Bass	USGS	2002	Willow Creek	1	274	**.251**
Largemouth Bass	USGS	2002	Willow Creek	1	275	**.283**
Largemouth Bass	USGS	2002	Negro Bar	1	281	**.183**
Largemouth Bass	USGS	2002	Negro Bar	1	290	**.421**
Largemouth Bass	USGS	2002	Nimbus Dam (DAM)	1	292	**.240**
Largemouth Bass	USGS	2002	Alder Creek	1	301	**.367**
Rainbow Trout	USGS	2002	Negro Bar	1	177	**.097**
Redear Sunfish	USGS	2002	Willow Creek	1	80	**.065**

Common Name	Data Source	Year	Site	#	Total Length mm[1]	Mercury Wet (ug/g)
Redear Sunfish	USGS	2002	Mississippi Bar	1	87	**.106**
Redear Sunfish	USGS	2002	Willow Creek	1	112	**.078**
Redear Sunfish	USGS	2002	Willow Creek	1	114	**.101**
Redear Sunfish	USGS	2002	Negro Bar	1	116	**.041**
Redear Sunfish	USGS	2002	Willow Creek	1	116	**.092**
Redear Sunfish	USGS	2002	Willow Creek	1	117	**.135**
Redear Sunfish	USGS	2002	Willow Creek	1	122	**.104**
Redear Sunfish	USGS	2002	Willow Creek	1	126	**.071**
Smallmouth Bass	USGS	2002	Mississippi Bar	1	145	**.163**
Smallmouth Bass	USGS	2002	Alder Creek	1	174	**.107**
Spotted Bass	USGS	2002	Mississippi Bar	1	118	**.096**
Spotted Bass	USGS	2002	Alder Creek	1	300	**.488**

[1] Length was measured as total length—longest length from tip of tail fin to tip of nose/mouth.